Wheeler & Akers

Construction & Operation
Of an Oscillograph
Of the D'Arsonval Type

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THE CONSTRUCTION AND OPERATION OF AN OSCILLOGRAPH OF THE D'ARSONVAL TYPE

BY

EDMUND BURKE WHEELER
MILTON KENT AKERS

Thesis for Degree of Bachelor of Science
in Electrical Engineering

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1905

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May 26, 1905.

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Milton Kent Akers and Edmund Burke Wheeler

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering.

Morgan Brooks

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INTRODUCTION.

This thesis was not prepared with the intention of constructing a piece of apparatus of the most delicate type possible, nor for use in the study of any special problem, but to build and test an oscillograph of the D'Arsonval type, which should be fairly portable and of sufficient sensibility for any ordinary investigations.

The work was carried on under the direction of the Department of Physics of the University of Illinois, the construction work being done in the workshop of that Department.

The authors desire to acknowledge their indebtedness to Professor A. P. Carman, and to Professor Chas. T. Knipp, for the advice and assistance they have given, during the progress of the work, and for the facilities which have been placed at their command.

Edmund B. Wheeler.
Milton K. Akers.

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OBJECT -

The object of this thesis was to design, construct, and test an oscillograph of the D'Arsonval type, which might readily be set up for operation at any place, and whose parts were strong enough mechanically to be easily handled and adjusted without the use of fine instruments, yet at the same time delicate enough to give accurate results under ordinary conditions.

REFERENCES.

The following references have been freely used in the design of the apparatus.

1.- Recording Alternating Current Wave-forms by Duddell Oscillographs, Scientific American Supplement, May 28, 1904.

2.- Description of the Blondel Oscillograph, The New York Electrical Review, September 13, 1902.

3.- The Oscillograph and its Uses, by Lewis T. Robinson, in the Proceedings of the A. I. E. E., Vol. 24, April 1905.

4.- A Photographic Study of Alternating Currents. Thesis by Poole and Carpenter, University of Illinois, 1897.

5.- The Oscillograph ; its Construction and Uses. Thesis by J. F. Duffy, University of Illinois, 1903.

6.- The Duddell Portable Oscillograph, The Scientific American, June 20, 1903.

7.- Experiments on Alternate Current Arcs, by Aid of Oscillographs, Duddell and Marchant, Journal I. E. E., Vol. 28, 1899.

ESSENTIALS OF A GOOD OSCILLOGRAPH.

An oscillograph for practical use should possess the following characteristics.

1.- A short free periodic time compared to the period of the wave form to be recorded.

2.- Critical damping, that is, the motion just ceases to be oscillatory.

3.- Negligible self induction.

4.- Sufficient sensibility.

5.- Parts strong enough mechanically, to be easily repaired and adjusted, by a person of ordinary skill, without the use of any fine or special instruments.

DESCRIPTION OF OSCILLOGRAPH AS CONSTRUCTED.

The apparatus consists essentially of a modified D'Arsonval galvanometer combined with a vibrating mirror, and a falling plate apparatus.

Figure 1. is a sketch of the galvanometer, showing the principle on which it works. In the narrow gap between the poles of a powerful electro-magnet are placed two parallel strips of phosphor bronze ribbon, formed by bending a strip over a small bone pulley (p), supported by a small spring (s), and the ends are fastened to two brass blocks (b).

If an alternating current is passed through this loop, one side will be displaced forward, and the other backward, at the

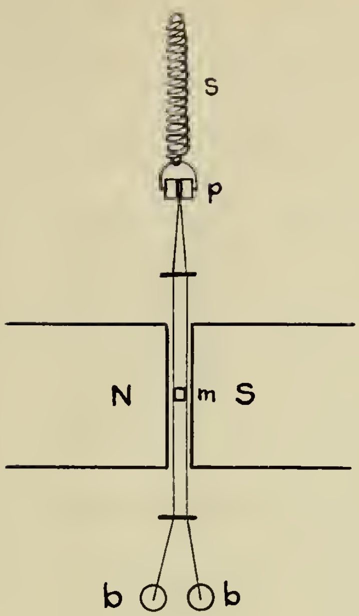

Figure 1.

same instant, and when the current reverses, the sides move in the opposite directions. If now, a small mirror is cemented to both sides of the loop, it will oscillate about a vertical axis, and if a beam of light is thrown on this mirror, it will be reflected in oscillations in a horizontal plane.

If a photographic plate is dropped vertically past this beam of light, it will trace on the plate the wave form of the alternating current.

/Plate 1. and Photographs 1. and 2. show the construction of the electro-magnet. The core is made of the best quality of Swedish iron, annealed, to make its permeability as great as possible. The two coils are wound on brass spools, and consist of 792 turns of No. 20 double cotton covered wire each, for the one system; and 796 turns each for the second system.

The pole pieces of the magnets are filed out of the same kind of material as the core. The angles at the back of the pole pieces were made 54° 44', which has been proved by Professor J. A. Ewing* to be the angle which will produce the greatest concentration of the lines of force in the air-gap. The magnet is mounted on a walnut base and is supported by three brass posts. The four terminals of the coils are brought to four binding posts at the rear of the base, in order that the two coils may be connected either in series or in parallel. On the front of the base, connected to two binding-posts, are two brushes of copper strip, which make contact with the movable system.

The vibrating systems are shown in Photograph 3. The support for the system consists of a piece of bone, this being well suited for the purpose, since it does not warp like hard rubber, and is also a good insulator. At the upper end of the support, and fastened to it by two screws, is an L shaped piece of brass which carries the adjusting screw and lock nuts. Fastened to the end of this screw is the spring (s), which is made of spring steel wire 0.315 mm. in diameter, and to the lower end of which, is fastened a small stirrup carrying the small bone pulley (p), over which the movable system is looped. Into the lower end of the bone support are screwed two small brass filister head screws, to the heads of which are soldered

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* Ewing, Magnetic Induction in Iron and other Metals, P 139.

the ends of the movable system. Two small wedge shaped bone bridges are fastened to the support by means of threads cut in them, which screw into holes tapped out in the support.

On the top of each bridge are two grooves, in which the movable system rests. The movable system consists of a phosphor bronze ribbon 0.02 mm. thick and 0.5 mm. wide, which passes up over the bridges, around the pulley (p), back over the bridges, and the ends soldered to the two screws. The sensitiveness of the system depends upon the tension in the spring (s) and the length between the two bridges.

The mirror is fastened to the vibrating system by means of melted shellac. The mirrors used were cut from a concave galvanometer mirror, having a focal length of 55 cm., to the dimensions of about 1.5 mm square.

On the back of the bone support of the movable system is fastened a brass block which fits over the top of a brass post (p) back of the pole pieces. This supports the movable system in position in the airgap.

The synchronous motor is shown in Photograph 4, and by Plate 2, and has been built following the design of the motor used by the General Electric Company in their apparatus.

The stator is built up of laminations of the best quality of transformer iron, and of the dimensions given on the Plate.

The coils are wound on fiber spools, and each consist of 745 turns of No. 25 double cotton covered wire. The two coils

are connected in series. The rotor consists of a piece of tool steel, of the shape shown in plate 2, the space between the four poles being filled in with hard rubber blocks fastened in place by small metal pins.

Since the motor runs on single phase current, a starting device must be employed, in order to bring the motor up to synchronism. This device consists of a four point cam, mounted on the shaft, which breaks the stator circuit through the contact maker (c), four times a revolution. When the motor is up to synchronism, the contact maker is lifted off the cam, and the circuit remains intact, and the motor continues to run at synchronism. The direction in which the motor starts, depends upon the position of the cam on the shaft.

The synchronous mirror is operated by a cam, mounted on the end of the motor shaft which projects into the box.

This mirror is shown in Plate 3, and Photograph 5. Resting on the cam (c) is a small rod, which is fastened to the mirror and is held against the cam by a spring (s), so that the mirror is moved in one direction by the cam, and is returned to its origional position by the spring. The mirror is mounted on a small block, and is held in position by two brass clamps, so as to be readily removable, when a photograph is to be taken.

The falling plate apparatus, for recording photographically the wave forms, is shown in Plate 4 and Photograph 6.

It consists of a light tight slideway of the dimensions shown in the figure, the lower end being closed by a removable block held in position by two brass stirrups. The upper end is closed by a similar block, through which project two brass tubes tt. The plate holder is made to accomodate a 4 X 5 plate, and fits loosely in the slideway. It is held in position in the slideway by a stop (s) on the back of the former. In order to give sufficient velocity to the plate in this short slideway, an initial velocity is given it by two steel springs which are held in position by the two brass tubes tt, and compressed when the cover is in place. In the front side of the slideway is a slit, closed by a shutter, through which the beam of light falls on the plate as it drops past.

THE OPTICAL SYSTEM.-

A diagram of the optical system is given in Plate 5. The source of light used is a 90° arc lamp. The path of the light through the apparatus is as follows. The light from the arc passes through a hole in the side of the box, back of the motor, to two small mirrors (m). From these mirrors, the light is reflected through two slits (s) to the mirrors (m)' mounted on the movable system. Here it is again reflected through a cylindrical lens (l) to the oscillating mirror (m"), or to the falling plate apparatus. From the synchronous mirror, the beam of light is reflected onto a piece of ground glass (g), when the wave form is to be examined visually.

The apparatus is mounted in a pine box, the internal dimensions of which are 30" X 12" x 12". The box is light tight except where it was necessary to cut through it, and these places were made as near light tight as possible.

The lid is cut in three pieces and hinged together, to enable the operator to get at the apparatus, and to view the waves on the ground glass. Binding posts are mounted on the back of the box, to enable the connections to be made without lifting the lid. A switch to open the field circuit of the system is mounted on the box, below the binding posts for the fields.

The box and apparatus were painted black, in order to avoid any reflections which might occur.

OPERATION.-

In order to view the wave form on the ground glass, or to take photographs of it, the procedure is as follows.

The arc is started and adjusted so that the light passes squarely through the opening in the box, to the reflecting mirrors.

These mirrors and the slits are adjusted till the two beams of light are reflected to the mirrors of the vibrating systems.

The vibrating systems are in turn adjusted, until the beams of light, after reflection from the vibrating mirrors of the movable system, are in turn reflected from the synchronous mirror to a common point on the ground glass screen. The synchronous motor is then started, which stretches the point of light into a band on the screen. The connections are then made to

the vibrating strips and the field switch is closed, which forms the waves on the screen.

In order to obtain the wave in one direction only, a sector of a disc of hard rubber is fastened to the shaft of the motor and revolves with it, preventing the light from entering the box, during the return of the synchronous mirror.

When a photograph is to be taken, the motor is stopped and the synchronous mirror removed, which allows the beams of light to pass through the opening at the back of the box.

The falling plate apparatus, which has been previously loaded in the dark room, is now attached to the box, and the beams of light are adjusted till they fall on the slit.

The cover is then placed on the box, the shutter covering the slit is opened, and the plate is released. The shutter is closed and the plate is taken to the dark room to be developed.

RESULTS AND CONCLUSIONS.-

With a free length of the vibrating systems of 4 cm., a period of about 0.001 second has been obtained, which has been found to be sufficiently sensitive for current and pressure curves from a 60 cycle alternator. On account of the natural period of the vibrating systems, it has been found necessary to use some method of damping. This has been accomplished by placing a drop of heavy oil between the pole pieces, below the mirror, where it is held in place by the surface tension. The period could be reduced considerably by employing finer

strips of phosphor bronze. Strips about one fourth the size of that used were tried, but they proved too delicate for the conditions to which they were subjected. As strips of an intermediate size were not at hand, and on account of the limited time for the completion of the work, the larger size was employed in all the data obtained.

A current of from 0.03 to 0.05 ampere in the strip, was found to give sufficient amplitude to the wave forms, with a field current of about one ampere. On 110 volt circuits, the current in the strip was reduced to the proper value by placing two 220 volt lamps in series with it.

The following suggestions are offered as a means of improving the apparatus. A new box of more substantial material, and wide enough to accomodate a third system, should be built. The optical system could be improved, by replacing the reflecting mirrors by small total reflection prisms, and by silvering the face of the synchronous mirror.

The cylindrical lens used was too short to obtain a large amplitude of the waves, and the focal length was too long to give a very sharp image. A new lens with a shorter focal length, somewhat longer and narrower, could be employed with better results.

A shorter period and greater sensitiveness of the vibrating system could be secured, by using a phosphor bronze ribbon about one half the size of that used, and which would yet have

sufficient mechanical strength.

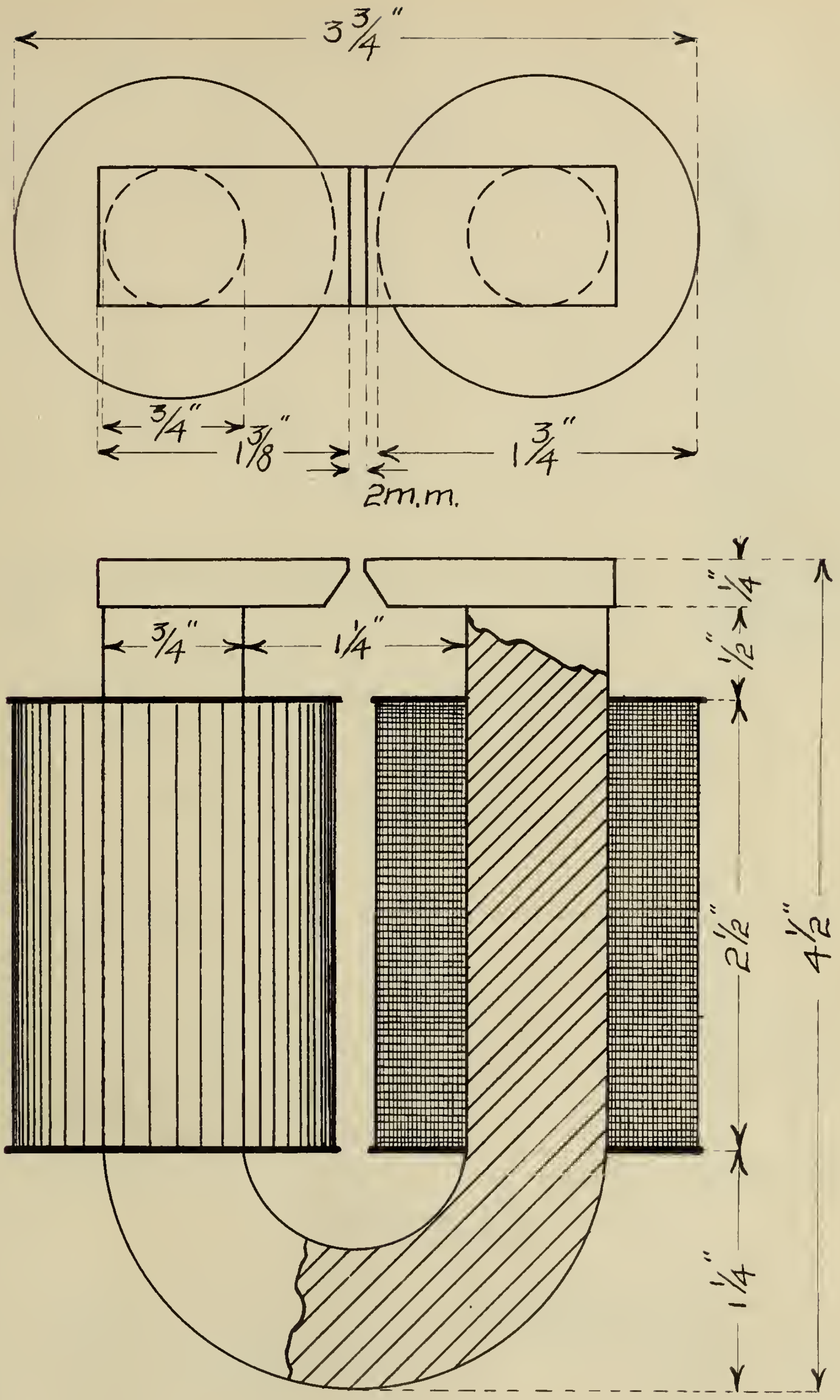
It was the desire of the builders to make these alterations, but on account of the limited time, it could not be accomplished.

DATA.-

The curves were obtained from the machines in the University Power Plant. The first curves were taken from the lighting circuit of the Engineering Building, hence were altered in form by the transformers in the circuit.
Angles of lag and advance, and the consequent changes in the wave forms, were produced by the various combinations of capacity and inductance, which were introduced in the circuit.
The individual characteristics of the alternators in the Plant were such as to enable the operator to distinguish readily, the machine which was in use, by the form of the electromotive force wave.

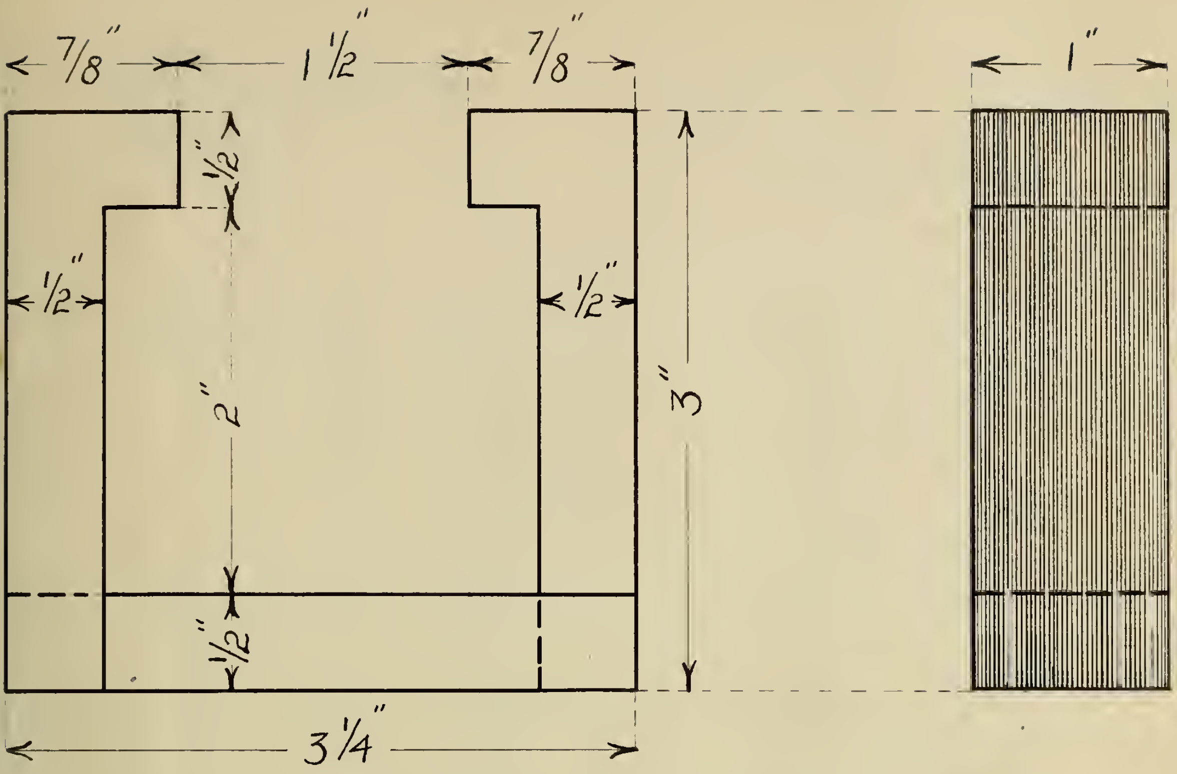
Some investigations were made to determine the effect of the Aluminium-Carbon cell upon the electromotive force and current wave forms in circuits containing these cells. The exact conditions, under which these curves were taken, are given under the individual curves.

Further experiments are expected to be made, and the curves incorporated in this thesis. The conditions under which they are taken, will be given with the curves.

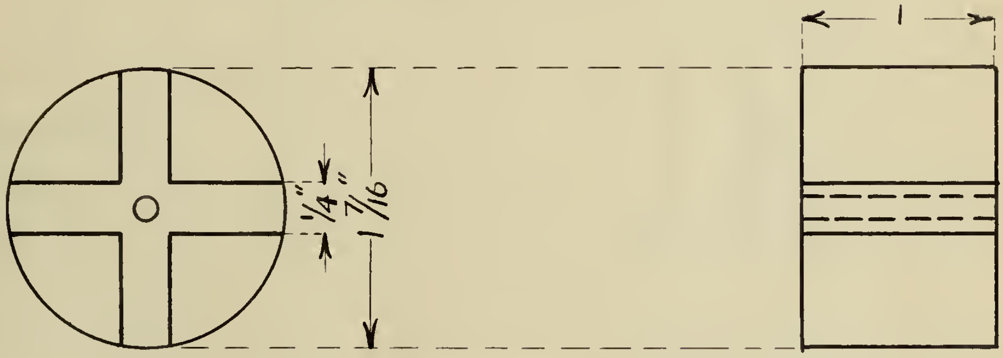


Field Magnet

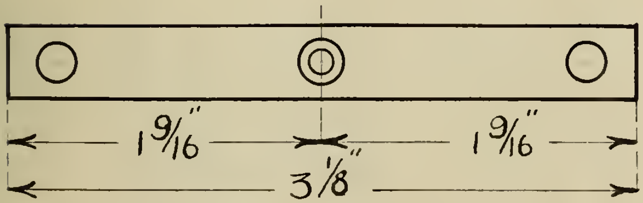
PLATE 1.



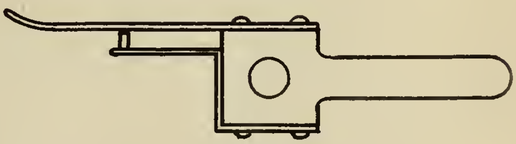
Field Magnet Core.



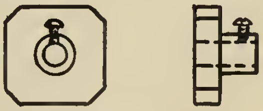
Armature.



End Plate.



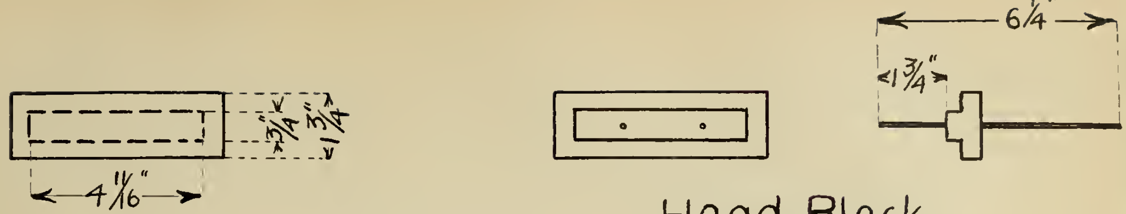
Contact Maker.



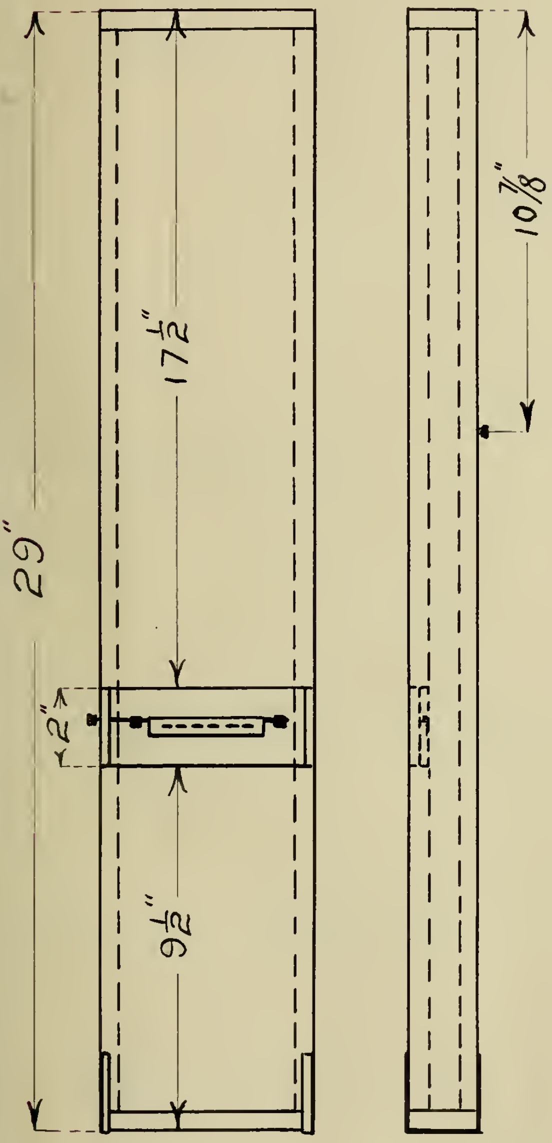
Cam.

Synchronous Motor.

PLATE 2.



Head Block.



Slideway.

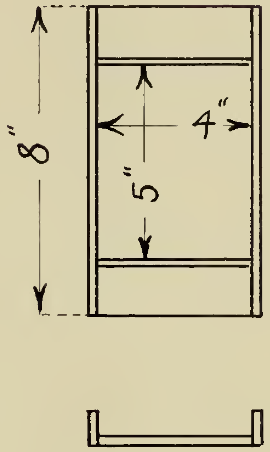
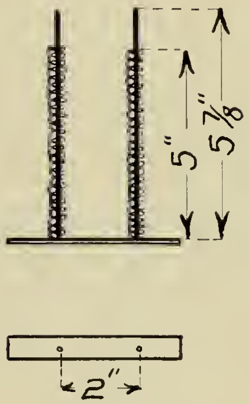


Plate Holder.



Springs.

Falling Plate Apparatus.

PLATE 4.

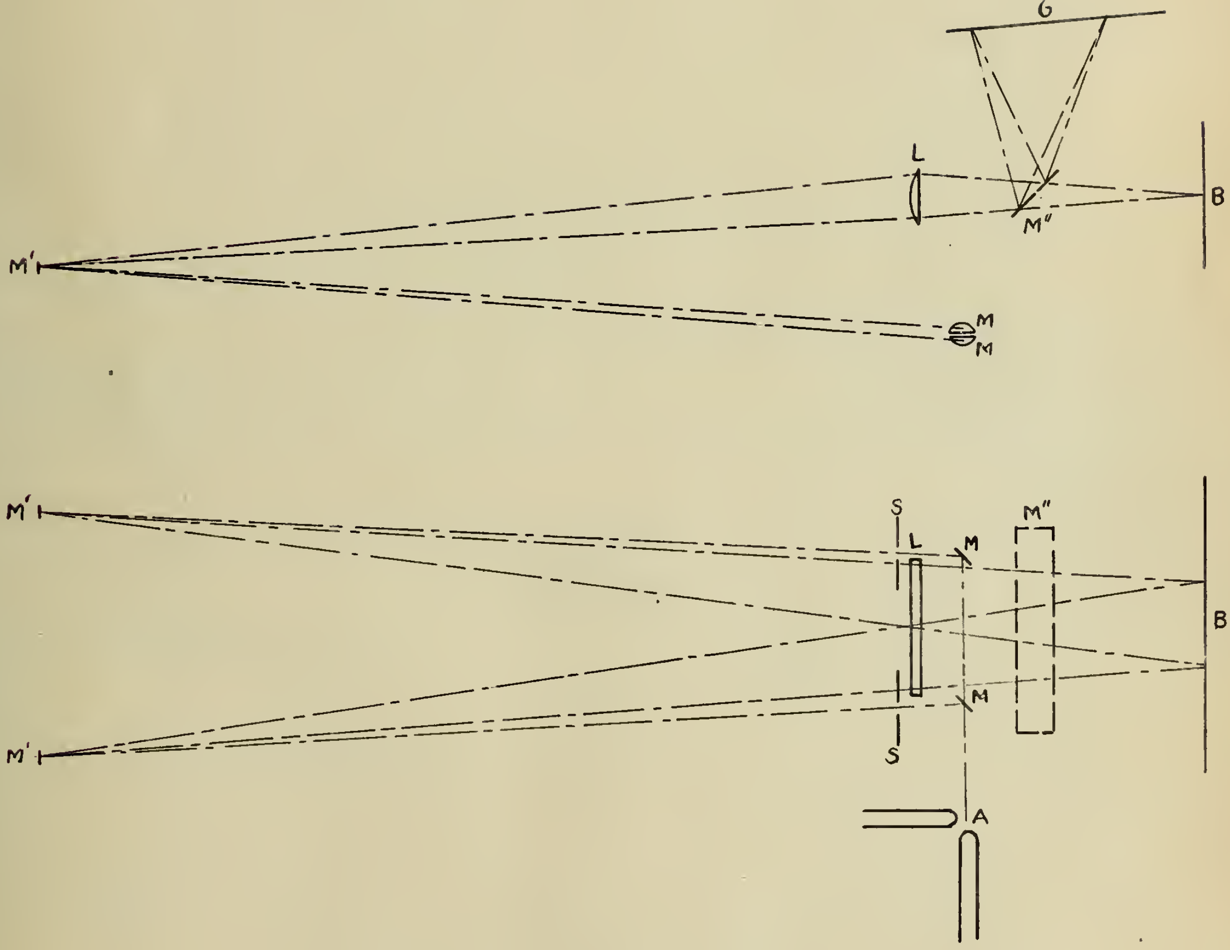


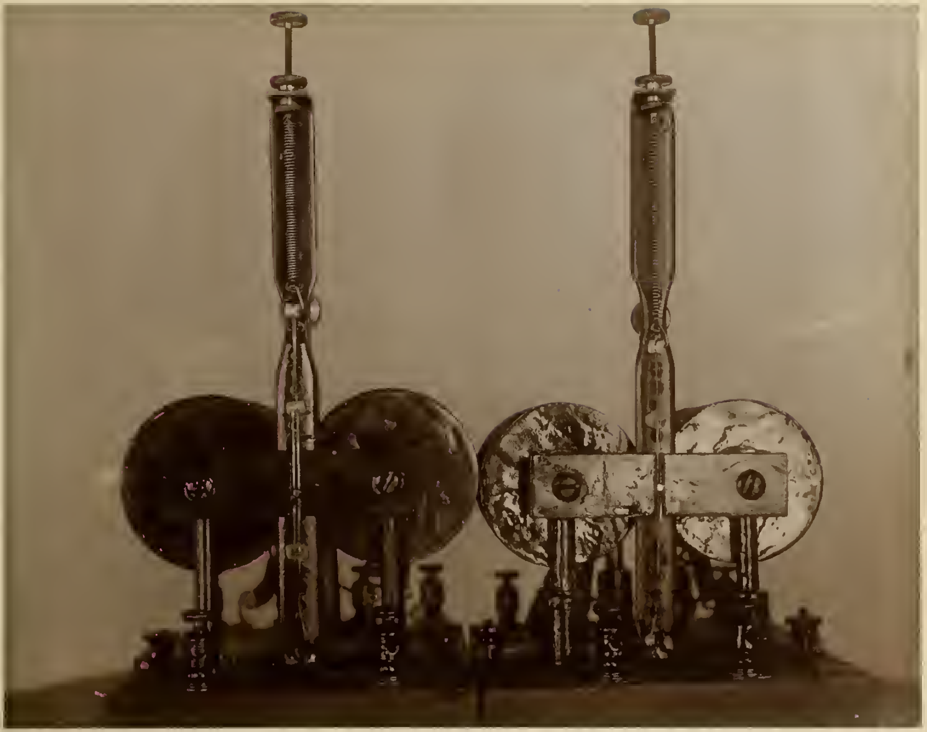
Plate 5.

The Optical System.

PHOTOGRAPHS

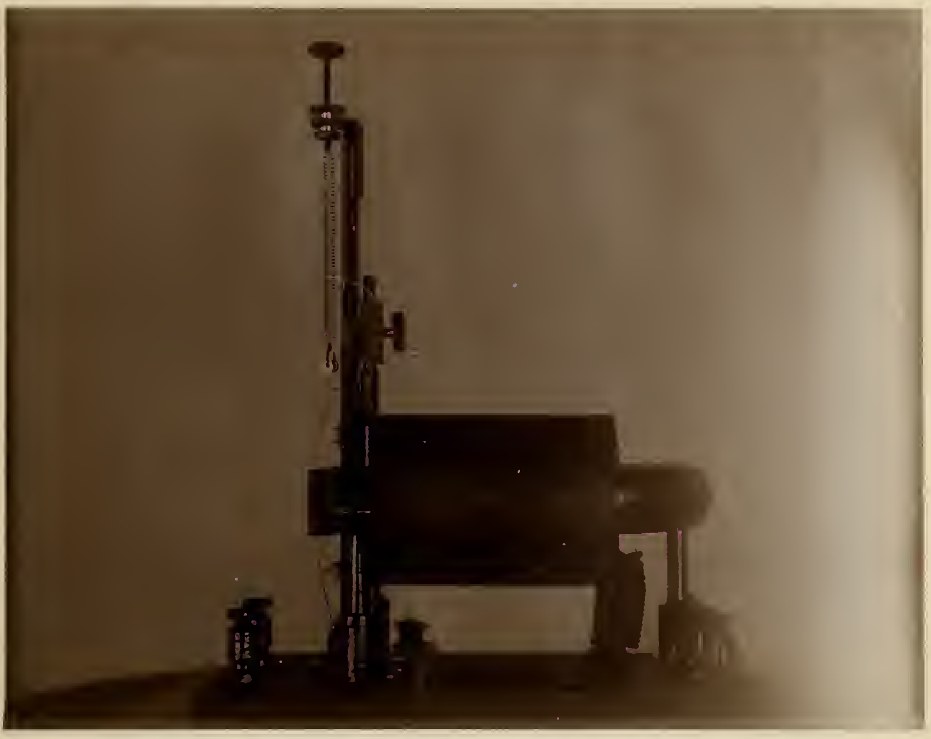
of

APPARATUS.



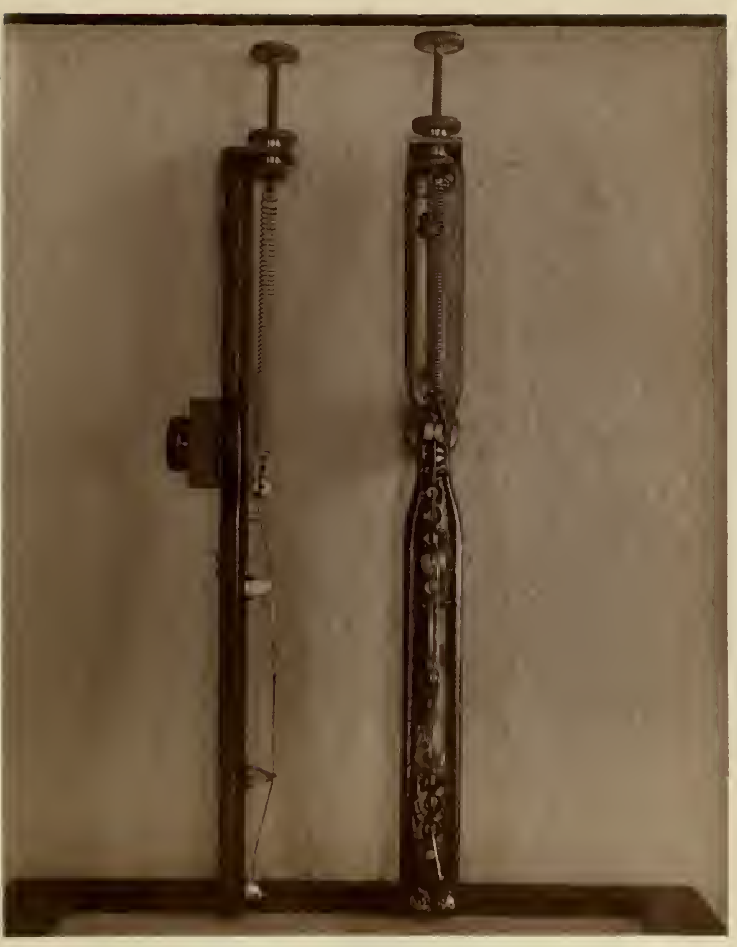
Photograph 1.

Front View of Galvanometers.



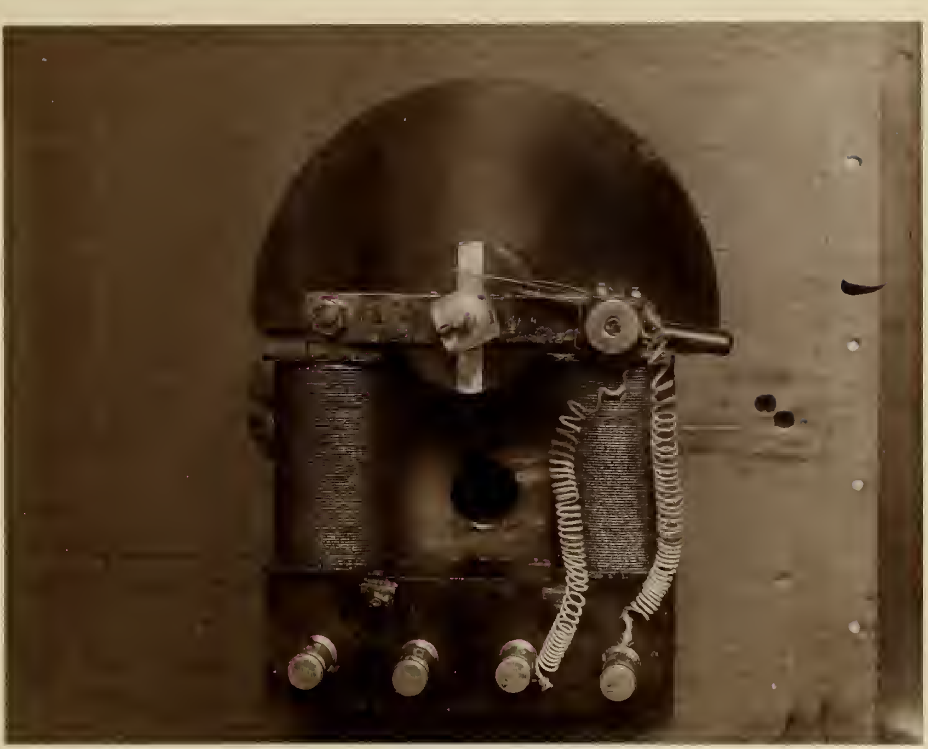
Photograph 2.

Side view of Galvanometer.



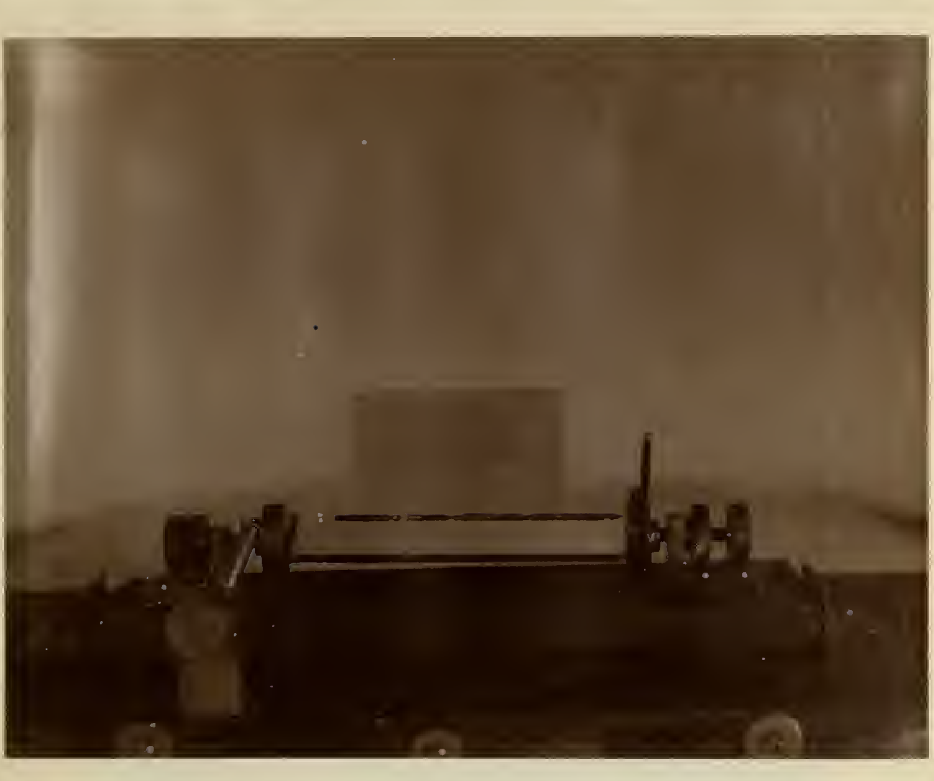
Photograph 3.

The Vibrating Systems.



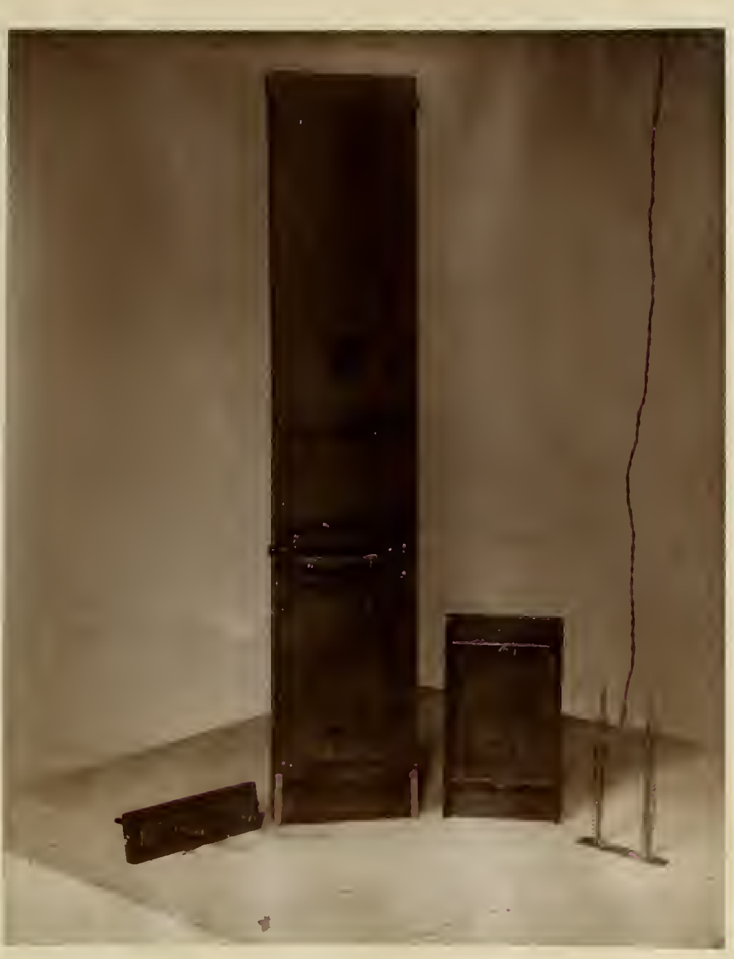
Photograph 4.

The Synchronous Motor.



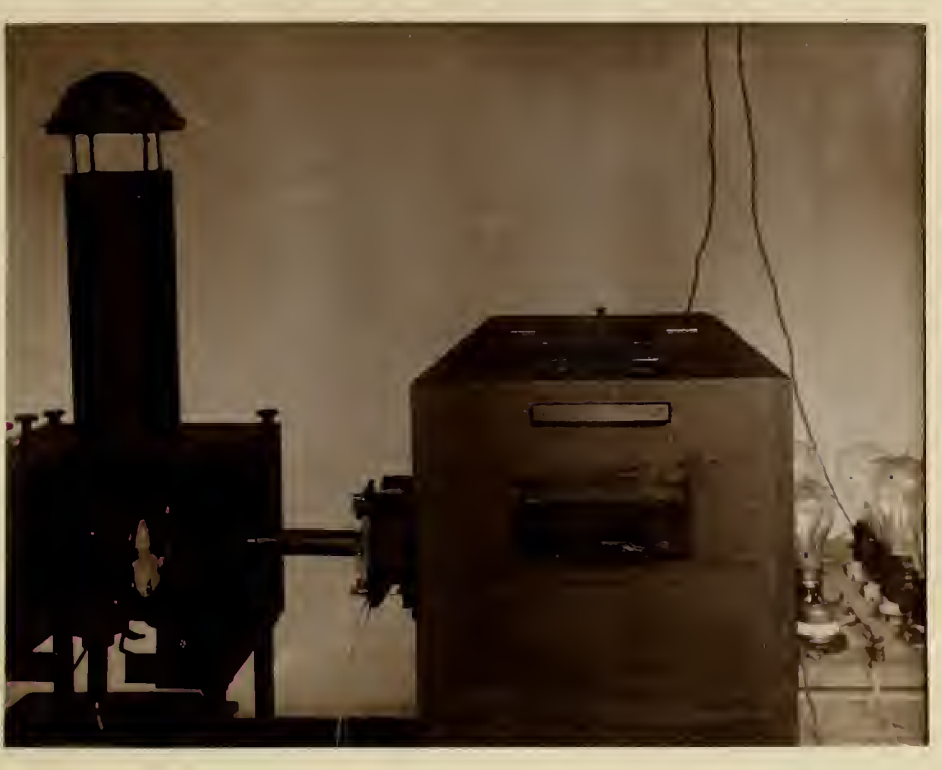
Photograph 5.

The Synchronous Mirror.



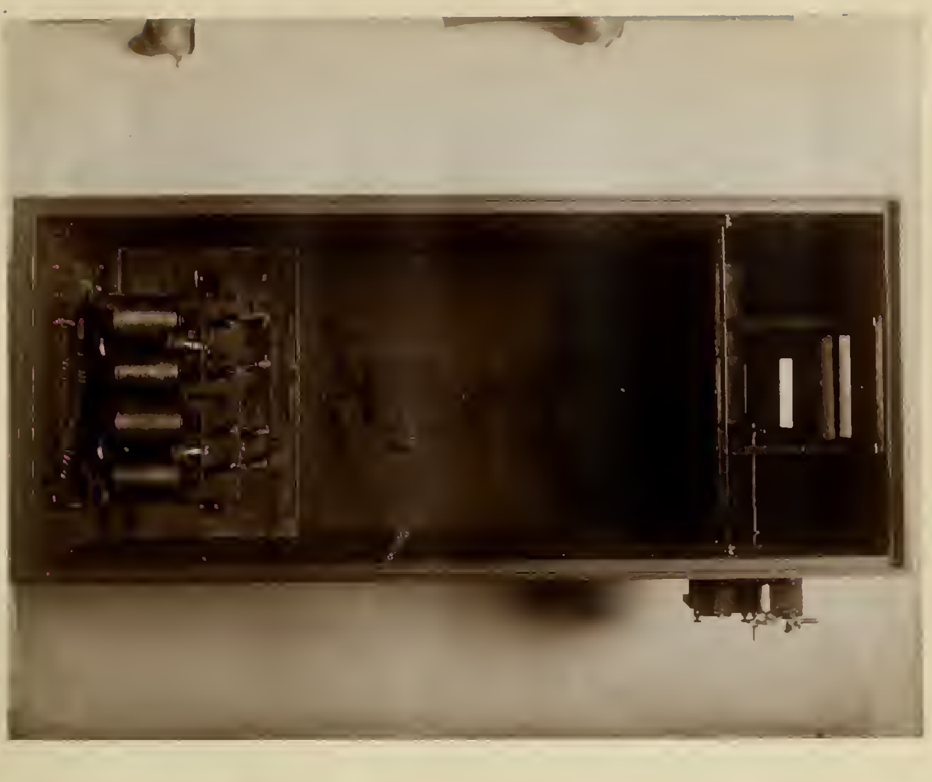
Photograph 6.

The Falling Plate Apparatus.



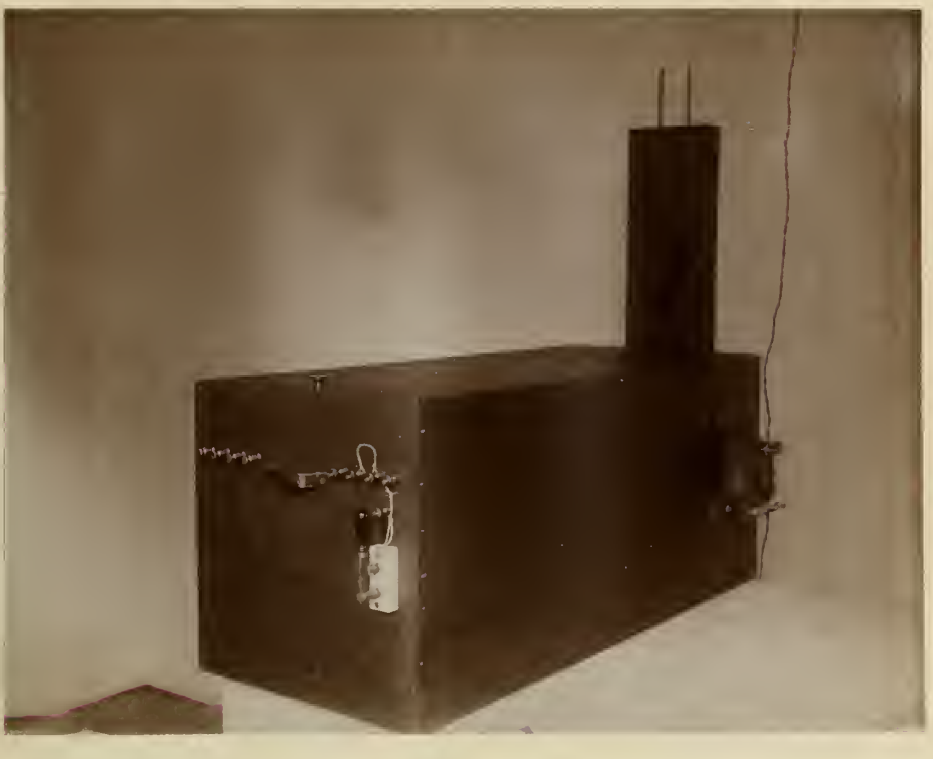
Photograph 7.

End View of Box, showing position of Arc Lamp.



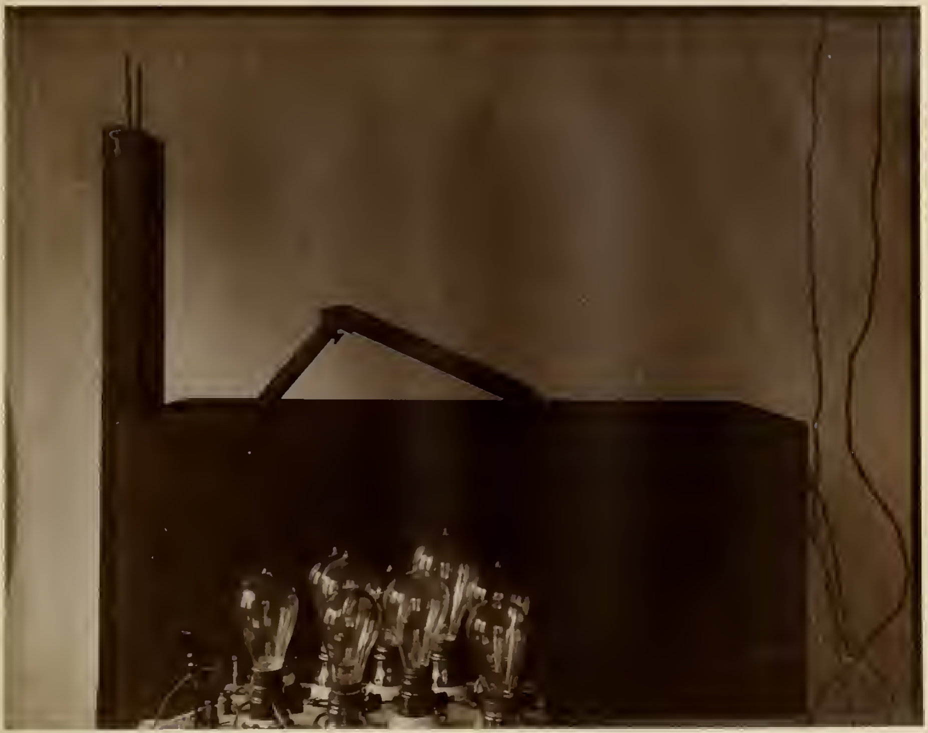
Photograph 8.

View from top of Box, showing position of Galvanometers, Synchronous Mirror, and Motor.



Photograph 9.

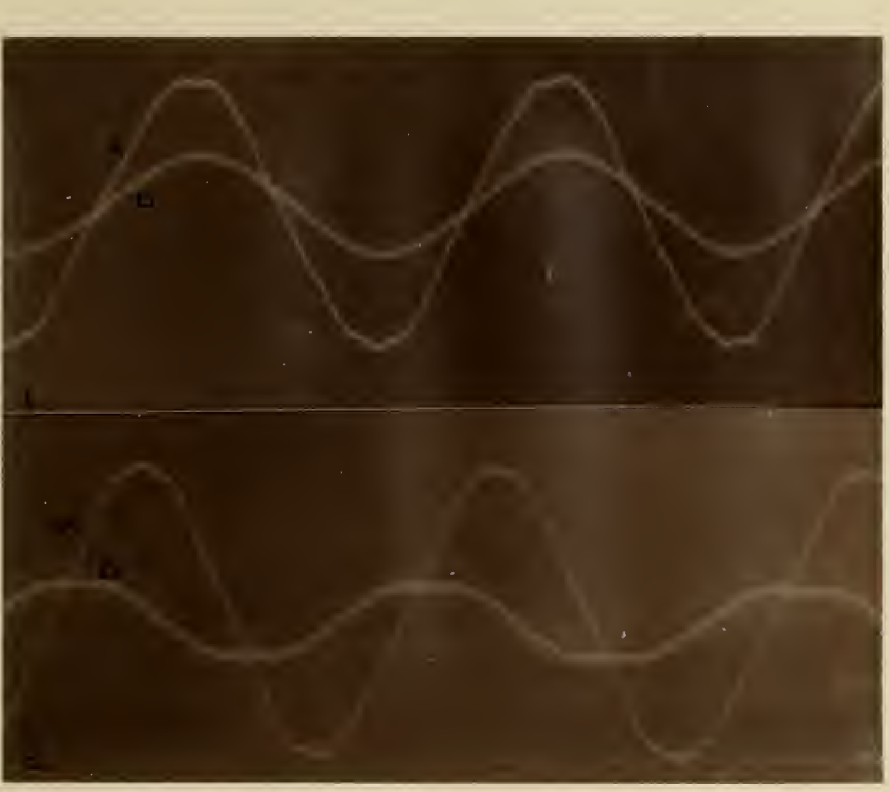
Rear view of Box, showing the connections to the Fields and the Movable Systems.



Photograph 10.

Side view of Box, showing the Falling Plate Apparatus in position.

CURVES.



Photographs 1 and 2.

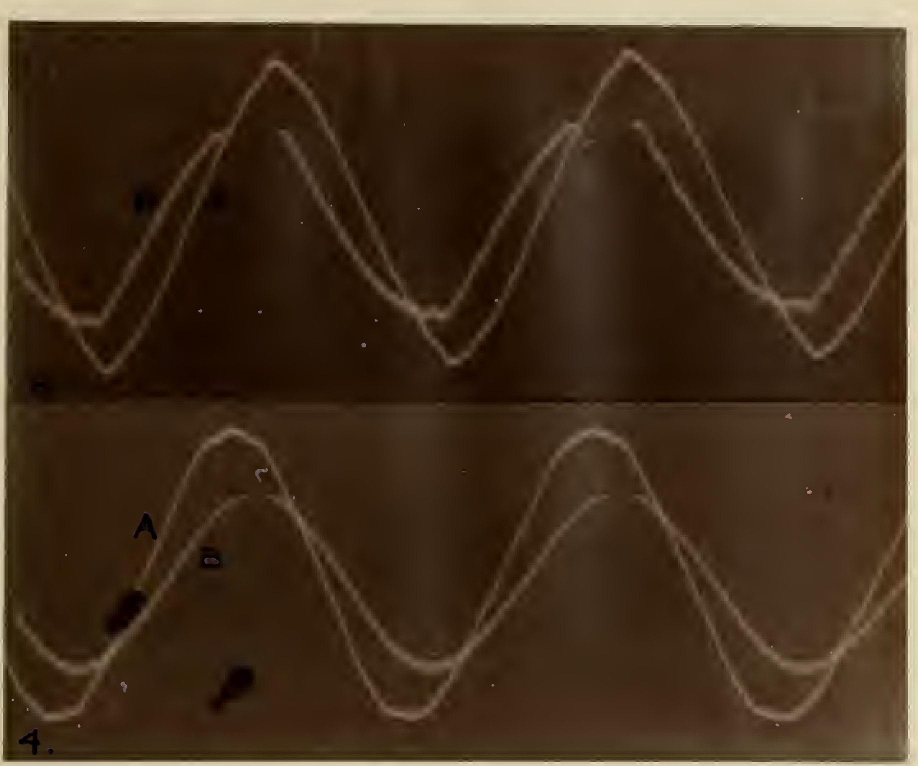
Westinghouse 75 KW. Alternator.

Capacity and Inductance in Series.

A - E. M. F. across line. B - Current.

1. Inductance predominating.

2. Capacity predominating.

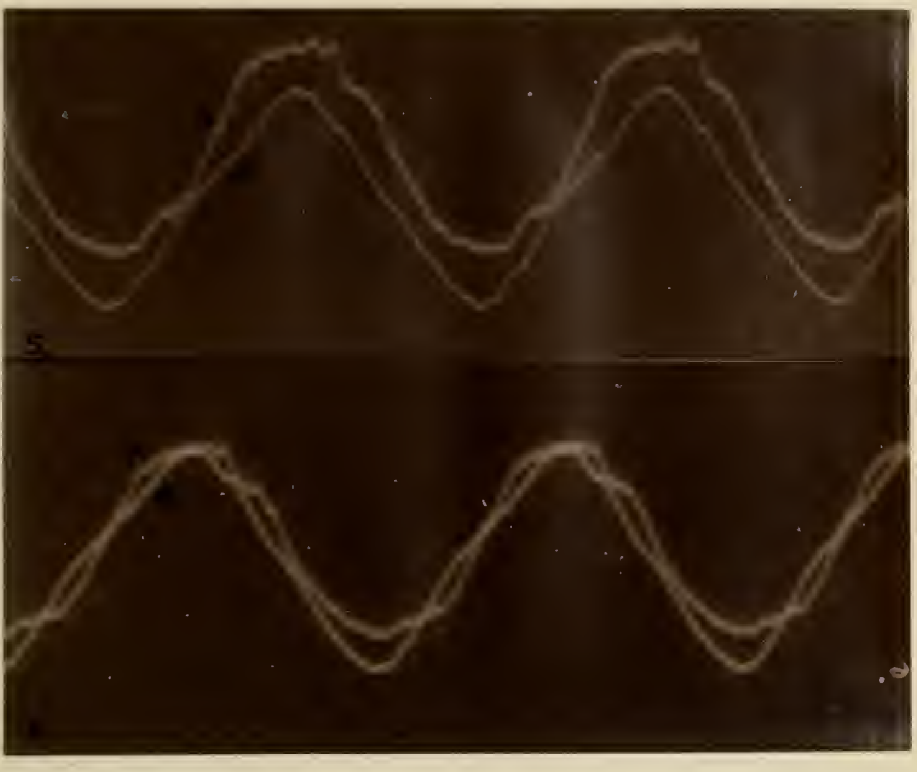


Photographs 3 and 4.

Westinghouse 75 KW. Alternator.

A - E.M.F. across line.   B - Current.

3. Capacity alone.   4. Inductance alone.



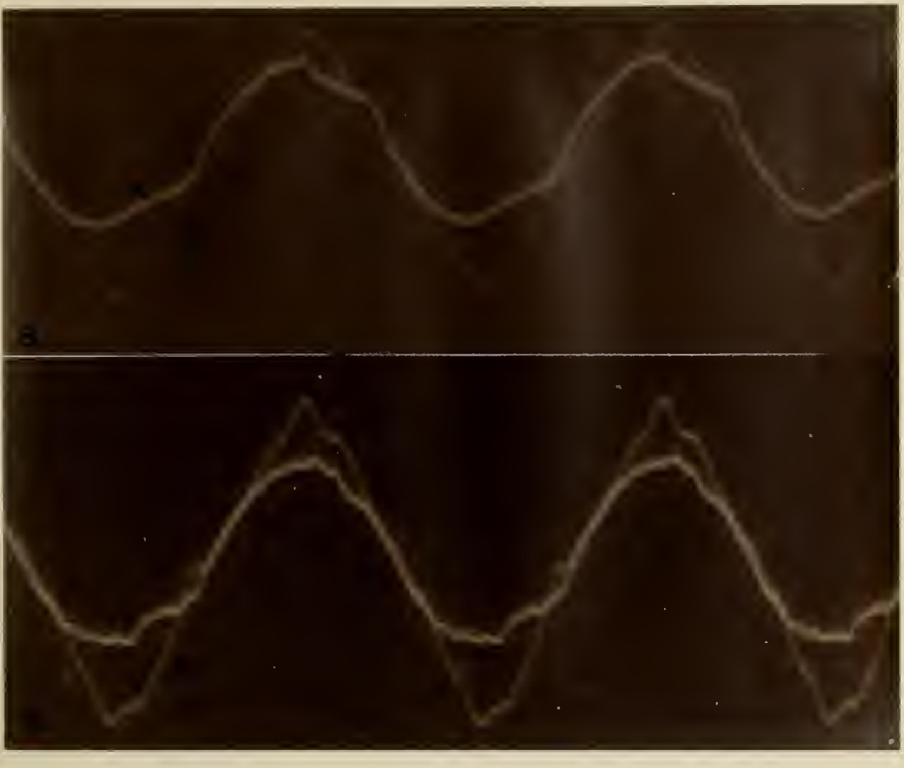
Photographs 5 and 6.

Westinghouse 75 KW . Alternator.

Curves from a hand-fed Arc Lamp.

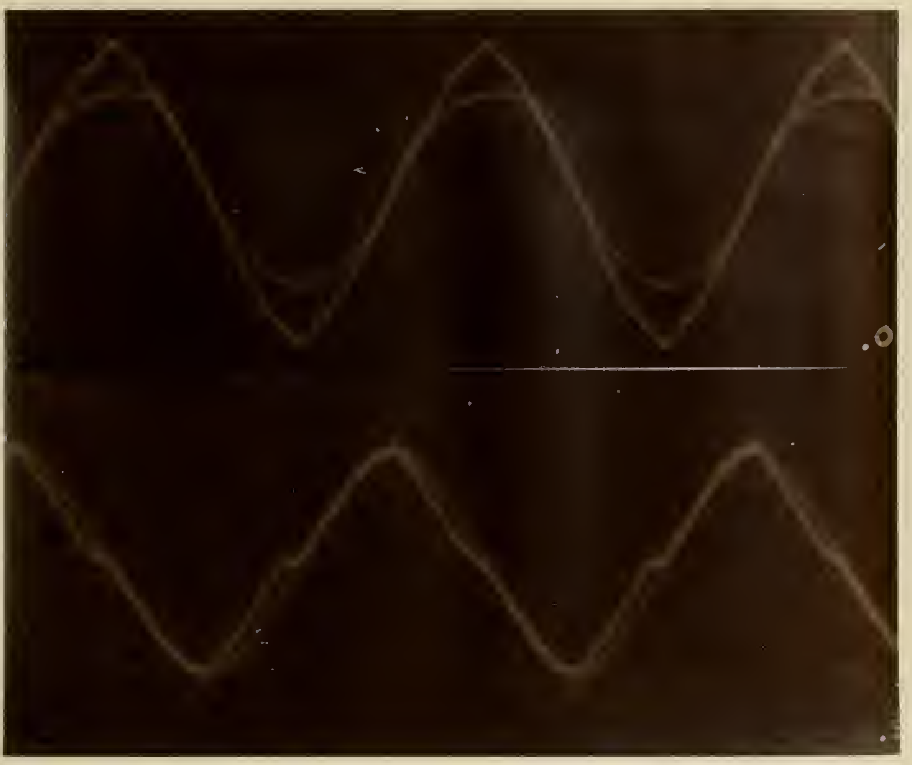
A - Potential Difference across the Arc.

B - Current through the Arc.



Photographs 8 and 9.

Same Data as Photographs 5 and 6.



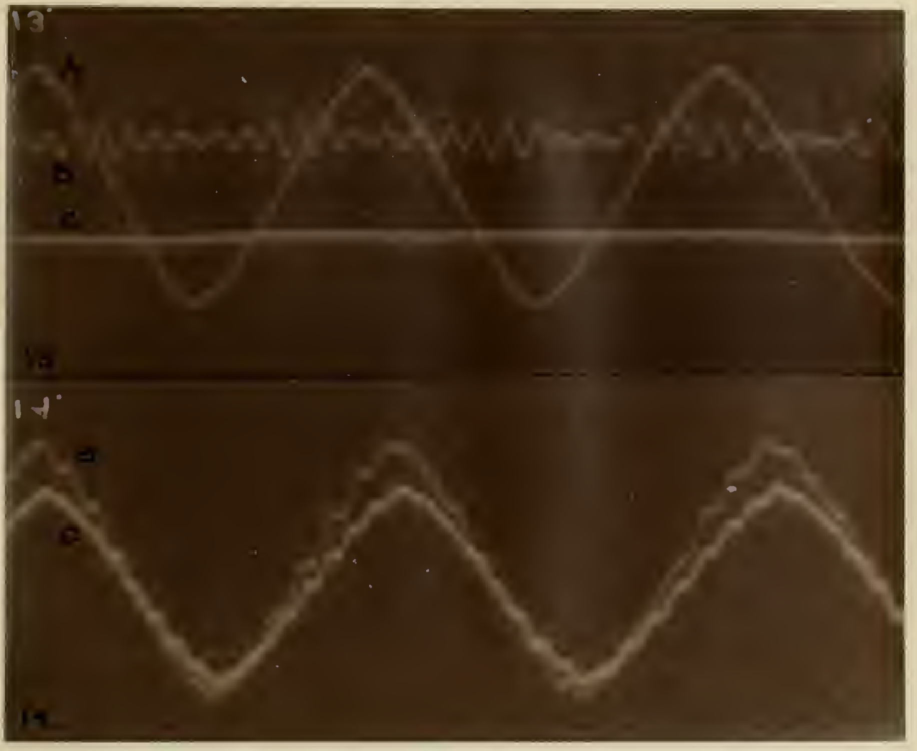
Photographs 10 and 12.

Westinghouse 75 KW. Alternator.

Arc Light Curves. A - E.M.F. across line.

10. B - Potential Difference across arc.

12. B - Current in Arc.



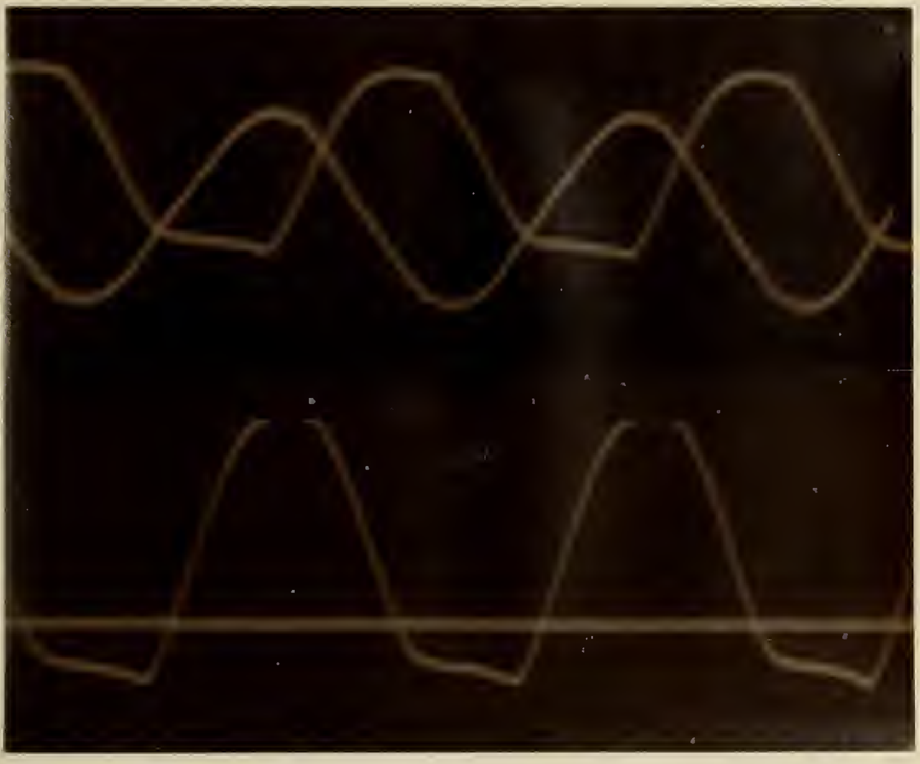
Photographs 13 and 14.

Westinghouse 75 KW. Alternator.

13. A - E.M.F. across line.

B and C, Vibrations of Systems undamped, and carrying no current.

14. B and C- E.M.F. curves. Systems undamped.



Photographs 15 and 16.

Westinghouse 75 KW. Alternator.

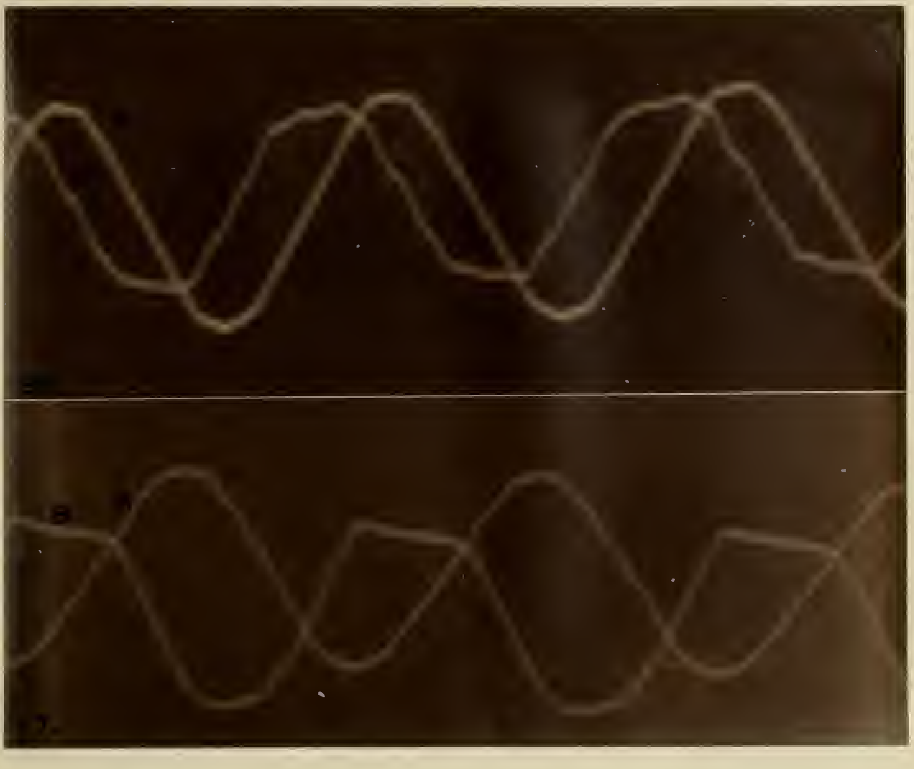
Curves from Carbon-Aluminium cells.

15. A - E.M.F. across line.

    B - E.M.F. rectified by cells.

16. A - Zero line.

    B - E.M.F. rectified by cells.



Photographs 22 and 17.

Westinghouse 75 KW. Alternator.

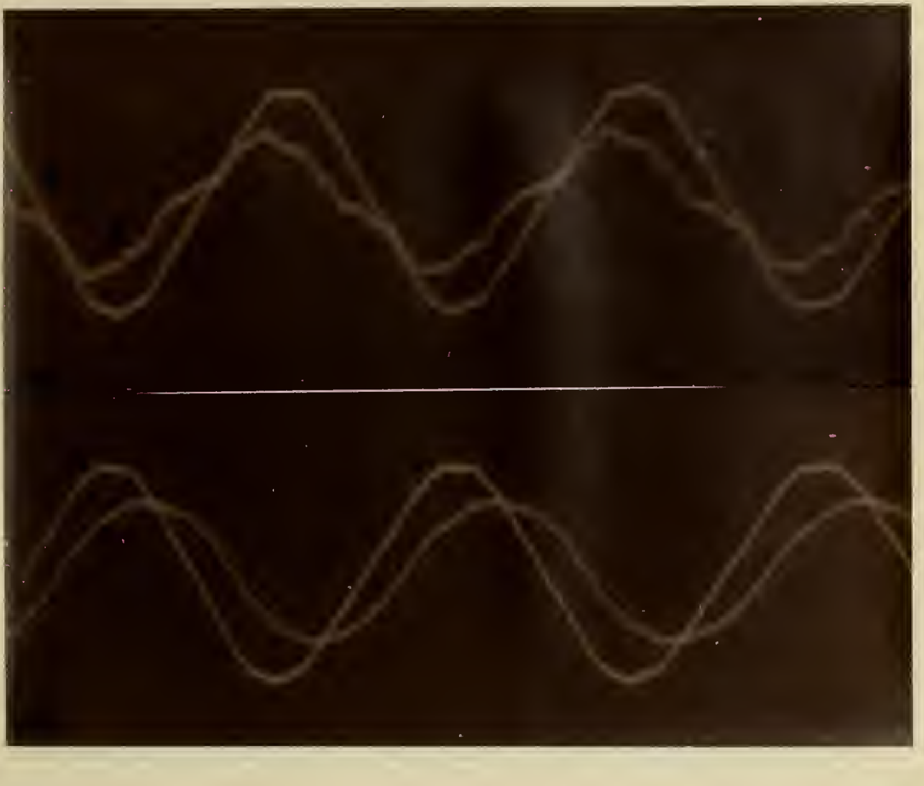
22. A - E.M.F. across line.

B - Current through a Condenser.

17. A - E.M.F. across line.

B - Rectified E.M.F. from Carbon-Aluminium cells.

These curves show the comparison of the angles of advance produced by condensers and by the cells.



Photographs 18 and 19.

Westinghouse 75 KW. Alternator.

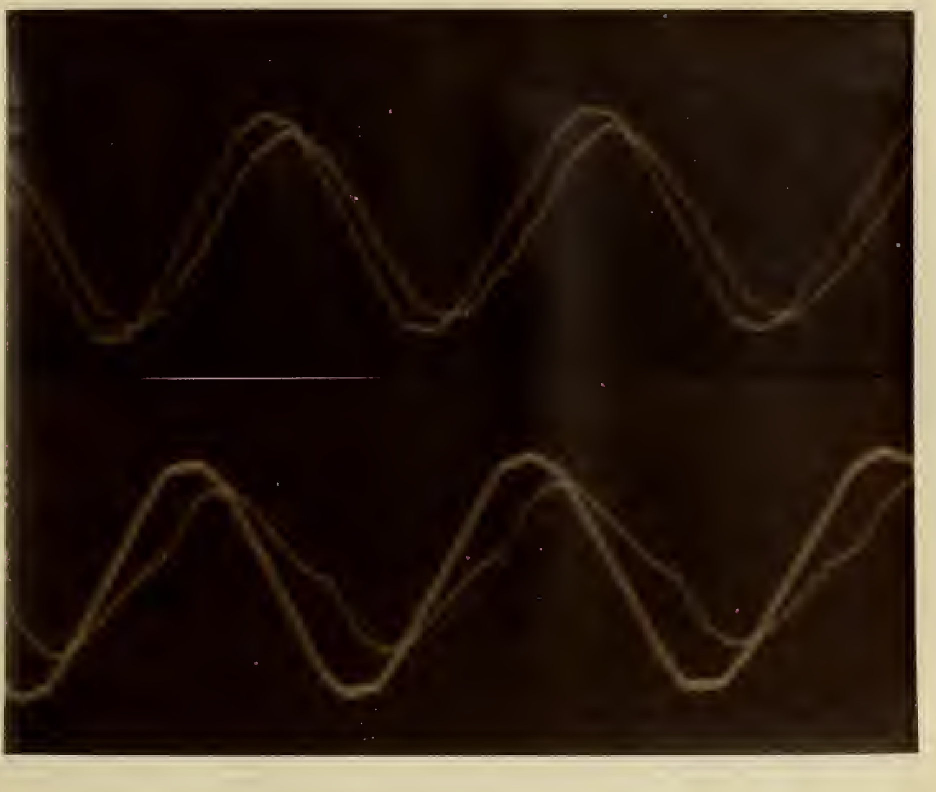
Capacity and Inductance in Parallel.

18. A - E.M.F. across line.

    B - Current, Capacity predominating.

19. A - E.M.F. across line.

    B - Current, Inductance predominating.



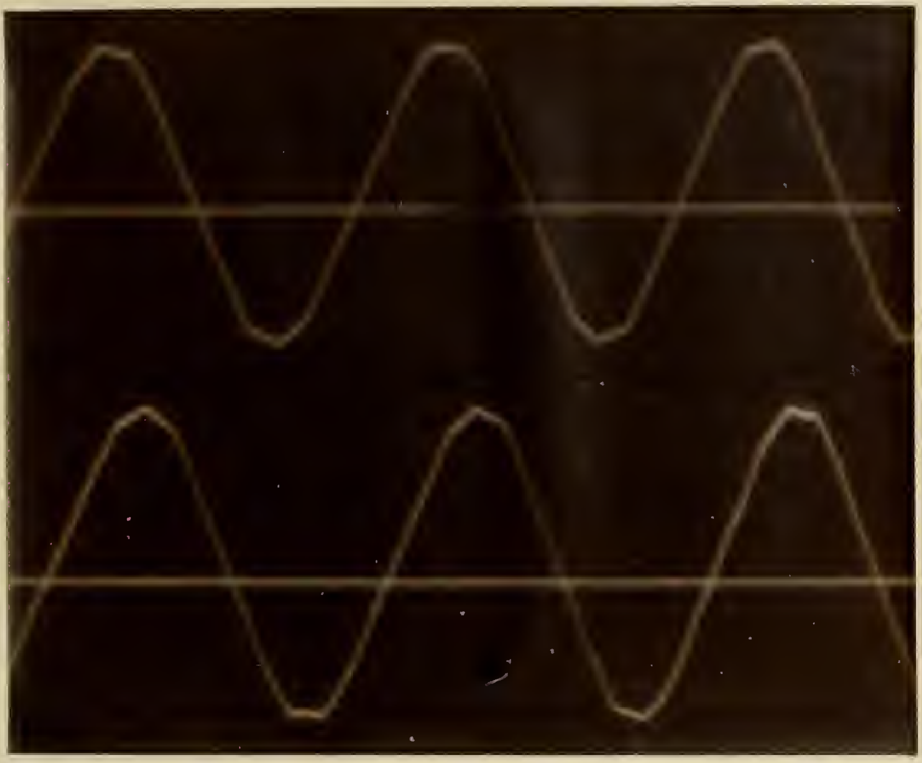
Photographs 20 and 21.

Westinghouse 75 KW. Alternator.

Fan Motor Curves. A - E.M.F. across line.

20. B - Current, running position.

21. B - Current, running on starting notch.



Photographs 23 and 24.

Westinghouse 75 KW. Alternator. E.M.F. curves.

23. Maximum tension on Vibrating System.

24. Tension on Vibrating System reduced.

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